TEST PROCEDURE

for

STATINTL [redacted] DIRECT IMAGE VIEWER

Project 7506

1.0 SCOPE

1.1 The Direct Image Viewer employs a unique optical approach involving diffraction gratings to provide an observer with an enlarged aerial image which can be viewed simultaneously with both eyes.

1.2 This document lists the tests and inspections to be performed that, when satisfactorily completed, show that the viewer meets the specifications listed.

2.0 APPLICABLE DOCUMENTS

2.1 [redacted] Specification for Direct Image Viewer, 25 August 1964.

2.2 Phase II Development of an Experimental Direct (Virtual) Image Viewer, 28 February 1964. (SECRET)

2.3 [redacted] Drawing 7506L1 Layout Dual Magnification Direct Image Viewer

2.4 Handbook for Direct Image Viewer

3.0 REQUIREMENTS

2.1 This viewer has been designed to meet the general requirements set forth in Section 3.2 of the document listed in Section 2.1. Consideration has also been given to the objectives listed in the Secret document listed in 2.2.

This is a prototype experimental viewer and therefore only the minimum specifications were imposed to allow for flexibility in the design and manufacture.

Section 3.2 of the specifications is listed below for convenience in verifying the test procedures.

Approved For Release 2002/06/17 : CIA-RDP78B04747A001500020043-7

3.1.1 Magnification - dual individual magnifications of 5X and 50X.

3.1.2 Observable Film Area - the observable film area shall consist of a nominal two inch by two inch square area in the film plane at 5X magnification, and two-tenths inch square area in the film plane at 50X magnification.

3.1.3 Film Size - the viewer shall possess a capability for viewing single frames of either 70mm or 4 x 5 inch film chips.

3.1.4 Exit Pupil Size - the nominal size of the composite exit pupil shall be 3.5 inches square.

3.1.5 System Resolution - at 5X magnification, the experimental direct image viewer shall be capable of providing a system AWAR resolution of 25 l/mm over the used field when referred to a high contrast target in the object plane. At 50X magnification, the viewer shall be capable of providing an on-axis resolution of 200 l/mm at the film plane with a high contrast target while employing commercially available lens. The resolution goal of the system, when operating at 50X, shall be 200 l/mm as viewed in the object plane for a low contrast (1.6:1) target.

3.1.6 Light Intensity - the illumination system shall be variable and will present to the eye, with an open film gate, at least that amount of light flux as presented to the eye by a lambertian source with illuminance of 100 ft-lamberts.

3.1.7 Illumination Spectrum - the illumination of the viewer system shall be contained in a narrow portion of the spectrum centered around 508.6 mμ.

3.1.8 Film Positioning - the viewer shall incorporate a provision for remote film positioning through X and Y translations to permit full coverage viewing areas for either 70mm or 5 inch film chips.

3.1.9 Focusing - a manual fine focus control shall be provided for each viewer lens magnification.

3.1.10 Film Temperature - the temperature of the film when mounted in the film plane of the viewer during operation shall not exceed ambient (75°F) by more than 20°F at an average density (silver) of 0.8.

3.1.11 Viewer Controls - the experimental direct image viewer shall contain a set of viewer controls, front panel mounted, consisting of the following:

3.1.11.1 Power - ON/OFF
3.1.11.2 Intensity of Illumination
3.1.11.3 Magnification Selector, 5X and 50X
3.1.11.4 Lens Focus, 5X and 50X
3.1.11.5 Film Translation
± two inch X
± two inch Y

3.1.12 Physical Size - (Reference Dwg. No. 7506L1). The viewer shall consist of the following general dimensions: length - 66 inches, height - 26 inches, width - 29 inches.

3.2 Theory of Operation

In direct viewing optical instruments, such as a microscope, the exit pupil is small, requiring that the operator place his eye close to the eye piece for satisfactory viewing. The present Experimental Direct Image Viewer, with its larger optical elements and diffraction grating, enlarges the exit pupil in a manner that the operator may view with both eyes the image and still have adequate head movement. In the absence of employing diffraction gratings in the present viewer, a single small exit pupil would exist, which would restrict the operator to the use of a single eye and no head movement when viewing at high

magnifications. Through the insertion of the gratings in the optical path, and the use of a narrow portion of the spectrum, many exit pupils are created, which when arranged side by side and placed both above and below one another, form a matrix of exit pupils in space providing an effective viewing area of 3.5 square inches, where the operator may place his eyes for viewing. This unique approach results from the use of a special field lens, and specially designed and built set of diffraction gratings. Near monochromatic light must be used with the viewer, or the diffraction characteristics of the gratings will produce multicolored exit pupil elements.

4.0 QUALITY ASSURANCE PROVISIONS

Acceptance test and inspection will be performed to show compliance with the requirements stated in Section 3.0.

4.1 Inspection

4.1.1 Inspect the viewer for overall workmanship in compliance with the statements made in Section 3.1 of the referenced specification. This statement is given below. The viewer shall employ materials of highest commercial quality consistent with its intended performance and specified operating environments.

Record comments in Section 6.1.1 of Data Sheet.

4.1.2 Determine physical size of machine and record in Section 6.1.2 of Data Sheet.

4.2 <u>Operational Test Procedure</u>

Details on how to perform the various steps and tasks required by this procedure are given in the viewer manual.

4.2.1 Prepare the viewer for operation. In performing this task connect volt and amp meter to the input line so that the power consumed may be measured and entered in Section 6.1.3.

4.2.2 Load the two film holders with 4 x 5 and 70 x 100 mm film chips.

4.2.3 Insert the 4 x 5 holder in the viewer.

4.2.4 Turn on the machine.

4.2.5 Vary the intensity over the full range.

4.2.6 Translate the film in X and Y over the entire format.

4.2.7 Check on the data sheet for compliance with requirements No. 3.1.3, 3.1.8.

4.2.8 Operate the 5X manual fine focus knob and run the image "through focus".

4.2.9 Change to 50X and operate the 50X manual fine focus knob to run the image "through focus".

4.2.10 Check on the data sheet compliance with requirements No. 3.1.1, 3.1.9 and 3.1.11.

4.2.11 Return to 5X magnification and remove the film chip.

4.2.12. Change the viewer to 50X.

4.2.13 Place a screen 13 inches in front of the viewer; at the exit pupil plane. Measure on this screen the size of the total exit pupil. Record this measurement on the data sheet, Section 6.1.6 for compliance with requirement 3.1.4.

4.2.14 Place a calibrated photometer probe in the exit pupil plane and measure the illuminance falling on the probe. The 3.5" x 3.5" exit pupil should contain 0.68 Lumens. This is equivalent to $\frac{32\ \mu\ \text{watts}}{\text{cm}^2}$.

Record the measurement made in Section 6.1.7 on the data sheet for compliance to requirement 3.1.6. As it can be shown by calculation that a lambertian source with an illuminance of 100 ft/lamberts places 0.68 Lumens in the exit pupil plane area.

4.2.15 Return to 5X magnification position.

4.2.16 Insert the 70mm holder containing the resolution target.

4.2.17 Translate the film so that the target appears in the center of the screen and adjust for best focus.

4.2.18 Read the resolution and record in Section 6.1.8 of the data sheet.

4.2.19 Move the target to all four corners of the viewing area and read and record the resolution on the data sheet. Verify that all readings are above the requirement stated in Section 3.1.5.

4.2.20 Center the resolution target and then translate to 50X.

4.2.21 Focus the lens and read and record the resolution on the data sheet in Section 6.1.9. Verify that the reading is above the requirement stated in Section 3.1.5.

4.2.22 Remove resolution target and replace with a film chip photograph.

4.2.23 Go through normal operations of scanning, viewing, focusing, changing magnification and so forth. Move head around to get an idea of latitude in head movement. Make any other checks that seem appropriate.

4.2.24 Record all comments in Section 6.1.10.

4.2.25 Comments on sections of requirements not covered by procedure.

1) Section 3.1.2 observable film area. With a grating aperture of 10 x 10 and the magnifications involved, the film areas observable are evident without testing. The optical dimensions are given in the Engineering Report.

2) Section 3.1.10, Film Temperature. There is no equipment available to measure this parameter. Therefore, the temperature rise listed in 3.1.10 cannot be actually determined. Satisfactory operation of the viewer, that is, no damage to the film, indicates that the temperature rise is within satisfactory limits.

4.2.26 Sign and date data sheet.

5.0 PREPARATION FOR DELIVERY

5.1 Inspect the shipping crate for suitability for shipment of the viewer. The shipping container is to be used for air freight delivery of the unit. In addition to the viewer, six spare projection bulbs and five copies of the instruction manual will be shipped.

6.0 NOTES

6.1 Data Sheet for Acceptance Test

6.1.1 Workmanship Comments

____
(signature of inspector)

6.1.2 Physical Size

Length __________ Height __________ Width __________

6.1.3 Electrical Power Consumed (magnification being changed and lamp at full brightness)

60 cps Volts ______ Amps _______ Watts __________

6.1.4 Compliance with Requirements 3.1.3 __________
Compliance with Requirements 3.1.8 __________

6.1.5 Compliance with Requirements 3.1.1 ____________
Compliance with Requirements 3.1.9 ____________
Compliance with Requirements 3.1.11 ____________

6.1.6 Size of exit pupil, compliance with requirement 3.1.4. Size (inches): ______________.

6.1.7 Intensity of Illumination
Microwatts/cm^2: ______________.

6.1.8 Resolution data 5X lens. Compliance with requirement 3.1.5.

Position	Resolution H	1/mm V	
On Axis	______	______	
Upper Right	______	______	
Upper Left	______	______	
Lower Right	______	______	
Lower Left	______	______	$\overline{HV}$
Average	______	______	____

6.1.9 Resolution Data 50X Lens - compliance with requirement 3.1.5. On axis resolution: 1/mm __________(h) __________(v) Average: __________.

6.1.10 Comments on General Viewer Operation:

6.1.11 Signatures of Participants:

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Quality Assurance ____________________

Inspector ____________________

Project Engineer ____________________

Customer Representative ____________________

____
(date)

Explanation of Formula in Section 3.1.4 and Transmission Value in Section 3.1.6

The accompanying drawing shows the four way overlap which occurs in the exit pupil plane. If the exit pupils were small, no overlap would exist; there would be an exit pupil matrix of 727 exit pupils. With the lens aperture size, optical distances and angular deviations of the grating, these overlap to produce 676 overlapped squares, each made up of four exit pupils as shown in the drawing.

In the simple case, Trial #1 (see Figure 1), the intensity of any of the 169 pupils were the function of the transmission in an order times any other order, such as 3% x 3% - .09%, or 4% x 5% = .20%. Then .2% x 129 would mean that 34% of the light flux is contained in the 13 x 13 exit pupil plane if all pupils had this combination.

In this case it becomes more involved. When the gratings are crossed each of the 727 exit pupils are made up in the same way that the other 169 orders were. When they are overlapped, the light flux in four of these pupil units are added to provide the total flux in this .142 x .142 area.

The total flux is now a summation of the following (see Figure 2):

	Y		X
Say pupil A is order	+4	x	+8
then pupil B is order	+4	x	+9
and pupil C is order	+3	x	+8
and pupil D is order	+3	x	+9

Also, only 1/4 of the flux in any pupil is used to make up this overlapped area (x).

$$\text{Then total flux} = \frac{A}{4} + \frac{B}{4} + \frac{C}{4} + \frac{D}{4}$$

$$= \frac{4 \times 8}{4} + \frac{4 \times 9}{4} + \frac{3 \times 8}{4} + \frac{3 \times 9}{4}$$

$$= \frac{1}{4}\Big((4 \times 8) + (4 \times 9) + (3 \times 8) + (3 \times 9)\Big)$$

The transmission is referred to the total flux without a grating, and therefore shows the relative intensity of the pupil units.

The general equation may then be written as

$$T_T = \frac{1}{4}\,(T_a \times T_b) + (T_a \times T_c) + (T_c \times T_b) + (T_c \times T_c)$$

T_T = total transmission of .142 x .142 overlapped exit pupil unit. Since transmissions are added (because the overlap occurs in the exit pupil plane), this total transmission is a relative figure showing what per cent of the total light flux falling on the grating is contained in this small square.

T_a, T_b, T_c, and T_d are individual orders such as 3 + 4 in the Y plane and 8 + 9 in the X plane.

The equation submitted before was wrong as a general equation. It is valid only where the X and Y orders are the same; that is, when a point is selected at, say, X and Y, 0 and 1, then

$$T_T = \frac{1}{4}\,(T_a \times T_b) + (T_a \times T_a) + (T_b \times T_b) + (T_a \times T_b)$$

$$= \frac{2(T_a \times T_b) + (T_a)^2 + (T_b)^2}{4}$$

(see previously submitted sheet for drawing)

Before when 3% was allowed in a single order as a minimum, a .09% would exist where this order overlapped itself. If the entire exit pupil was made up of these units 15.2% of the energy would be in the combined matrix (.09 x .169). Now when 676 overlapped units exist and the same minimum is allowed, it can be looked upon in the same way, i.e. 15.2% divided by the 676 units gives .0225% for each of the 676 units. The result of the previous equation T_T should always exceed .0225% to be above this allowable limit.

A 4:1 brightness difference could mean that T_T would vary from .0225% to .1%. An example is listed below.

The overlapped pupil is made up of order 3 + 4 in the Y direction and 7 + 8 in the X plane. Their individual transmissions are

Order	Transmission %	Plane
3	3	Y
4	4	Y
7	5	X
8	6	X

Then $T_T = \frac{1}{4}$ $(.03 \times .05) + (.04 \times .05) + (.03 \times .06) + (.04 \times .06)$

$T_T = \frac{1}{4}$ $.0015 + .0020 + .0018 + .0024$

$T_T = \frac{.0077}{4} = .0019 = .19\%$

Then 0.19% of total flux falls in this .142 x .142 area in the exit pupil plane.

BY ______ DATE ______ SUBJECT RELATIONSHIP OF COMBINED EXIT PUPILS

SHEET NO. ______ OF ______

CHKD. BY ______ DATE ______ JOB NO. 7506

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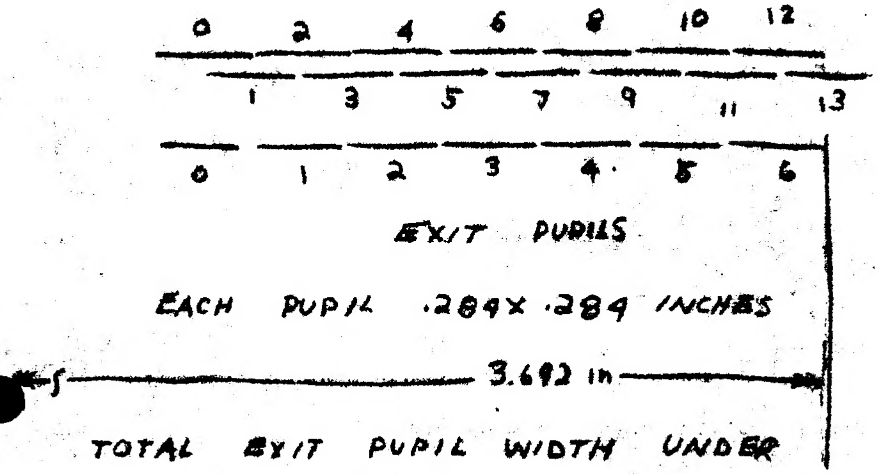


OVER LAP APPROACH

STANDARD METHOD

EXIT PUPILS

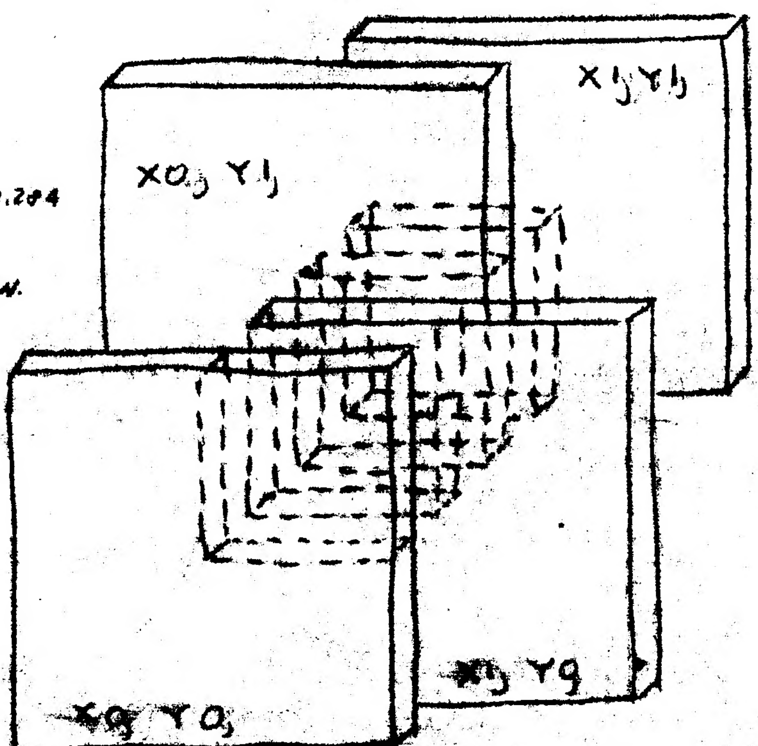
EACH PUPIL .284 X .284 INCHES

TOTAL EXIT PUPIL WIDTH UNDER CONTROL OF SPECIFICATION

EXIT PUPIL .284 X .284

OVER LAP AREA .142 X .142 IN.

FOUR EXIT PUPIL OVER LAP TO FORM ONE COMBINED ELEMENT



TYPICAL EXIT PUPIL OVERLAP

0 – 13 ORDERS

X →

Y